A WIDE BAND COUPLED LINE POWER DIVIDERUSING METAMATERIAL

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Abstract:A generalized wide band coupled-line power divider using square type metamaterial which is operating at frequencies from 0.5 to 3.5 GHz is proposed. The existing coupled lineWilkinson power divider which is operating at dual band of frequencies 1.1 and 2.2 GHz is extended to operate in the frequency range of 0.5 to 3.5 GHz using the metamaterial structure. The metamaterial which is essentially like a split-ring resonator is used at the output ports for the bandwidth enhancement. Thecoupled-line structure contains two lumped resistors 100Ω and 200Ω used for providing better isolation between the two output ports of the power divider. The proposed power divider using metamaterial has better results of S-parameters for wide band operation. Simulation has been done by HFSS 13.0.

Introduction: Various Power dividers are microwave components used for power division or power combining. The main function of a power divider is to split the input power into a number of smaller amounts of power as needed by the circuit or system.The power dividers have served a prominent role for years within the RF and microwave community. Wilkinson initially developed the power divider in the 1960s, and it is named after Ernest Wilkinson, the electronics engineer [1]. Modified power dividers to satisfy the dual-band operationsare explained in [2-4].A Coupled line has a compact structure, comparedto a conventional transmission line. A coupled line is not only used for its compact structure and it also provides more flexible and freedom of the design parameters [5]. The Wilkinson power divider, with coupled line structure was used only for a single band operation [6]. Frequency-ratio limitation is small in the case of the dual band power divider [7]. Now-a-days more research interest has gained in coupled line power dividers for a single or dual band operation [7-8]. The use of lumped element components [9-12], open / short circuit stubs [13-15] or only the resistors [16-18] have been proposed for the dual band Wilkinson power dividers so far. The existing power divider configuration is dual band coupled-line divider [19]. It uses Duroidsubstrate with a relative permittivity ε_r=2.2, and a thickness of0.76 mm. The dual band frequencies of the power divider are f_1=1.1 GHz and f_2=2.2 GHz with a loss tangent of$tan\delta$ = 0.008.The equivalent technique analysis and optimization technique is discussed in [20].

Theory and design of metamaterial: The main drawback of the existing power divider is it operates only in a dual band frequency. So to improve the coupled line power divider to widen the bandwidth, a metamaterial structure has been proposed. The Fig. 1showsthe geometryof the square split ring metamaterial.

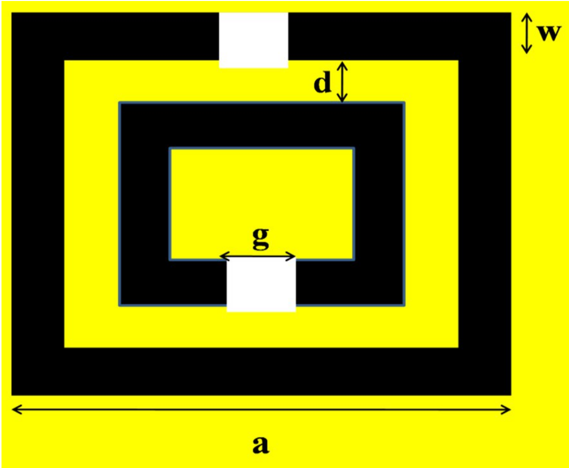

Fig. 1 Geometry of square split ring metamaterial

In the Fig.1,a- is the length of the outer ring, d- is the space between the inner and outer rings, w- the width of the ring and g- the gap in the ring. The gap between inner and outer ring acts as a capacitor while the rings themselves act as an inductor, resulting in an LC resonant circuit. The design equations for the inductor, capacitor and resonant frequency are given in (1) – (4) [20].

$$L = \frac{4.8\mu_0}{2}(a-w-d)\left[\ln\left(\frac{0.98}{\rho}\right)+1.84\rho\right] \quad (1)$$

Where,

$$\rho = \frac{w+d}{a-w-d} \quad (2)$$

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \quad (3)$$

$$C = \frac{1}{4Lf_0^2\pi^2} \quad (4)$$

The metamaterial structure is added at two output ports of the existing power divider.The output port length is 15mm, to fix the structure of metamaterial of 7 mm the output port is cut at the centre for 7 mm. The power divider is fabricated on a 0.79 mm thick Taconic RF-35 substratewith dielectric constant of 3.5 and loss tangent oftan $\delta = 0.008$.Here the essential parameters for the design is f_0=1.65 GHz.
It has two rings, i.e. inner and outer rings. The length of the metamaterial is 7 mm and width is 1mm in the outer ring,the length of the inner ring is 4 mm and width is 1mm.The space between the inner and outer ring is 0.5mm. The substitution of this values results in L=30nH, C = 0.3fF and f_0 = 1.65 GHz. The Fig. 2 shows the simulated result of the designed square split ring metamaterial structure.

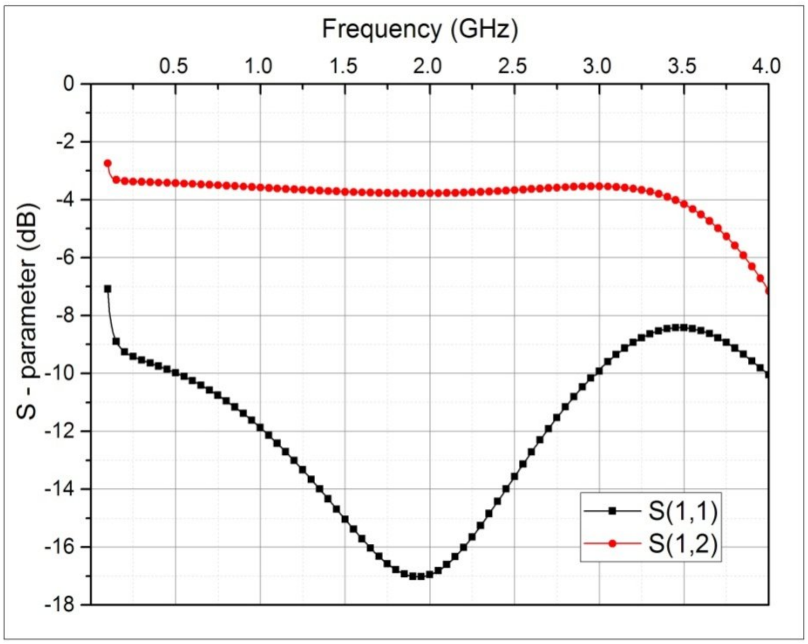

Fig. 2 The simulated result of designed square split ring metamaterial structure

PROPOSED WIDEBAND POWER DIVIDER

The proposed wide band power divider is designed to operate between 0.5 - 3.5 GHz using ANSOFT HFSS simulator. The power divider, simulated with the length of each coupled line is 23mm and the coupling space between the first coupled lines is 1mm and 0.6 mm for the second coupled line. The width for the first coupled line is 1mm and 1.4 mm for the second coupled line. The resistor values which are used between the coupled lines are 100 Ω and 200Ω. Simulation results show that the impedance matching for the proposed power divider strongly depends on the location of the Metamaterial. Thus the impedance bandwidth is widened by maintaining width and length of the coupled line structure. The Fig. 3 shows the layout of proposed power divider.

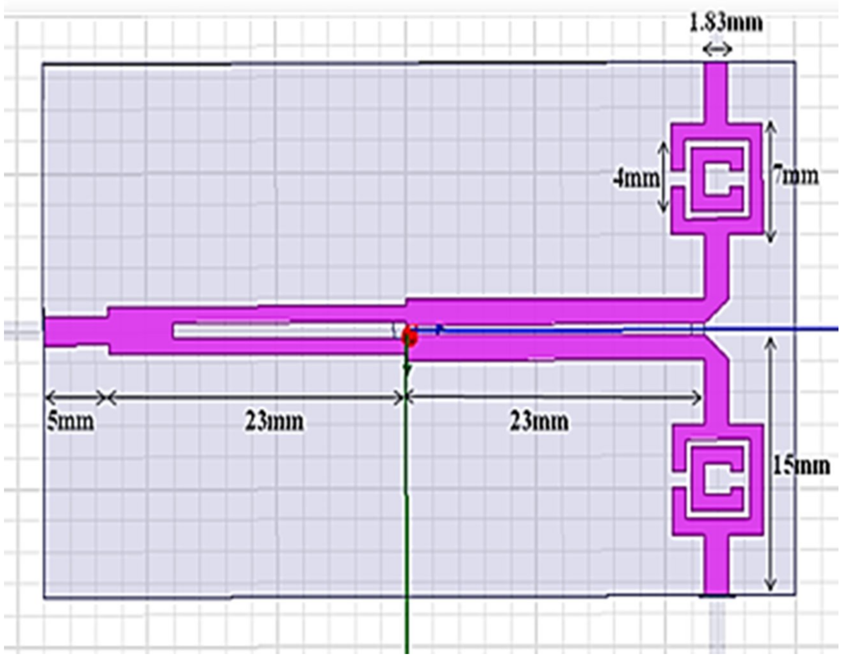

Fig. 3 Layout of the proposed power divider

SIMULATION RESULTS

It has been simulated by using the Ansoft HFSS.13 simulator (High Frequency Structure Simulator) and the scattering parameters are analyzed. The Fig. 4 shows the simulated S-Parameters S_{11}, S_{22}, S_{33}, $S_{21,}$ S_{31} and S_{23}.

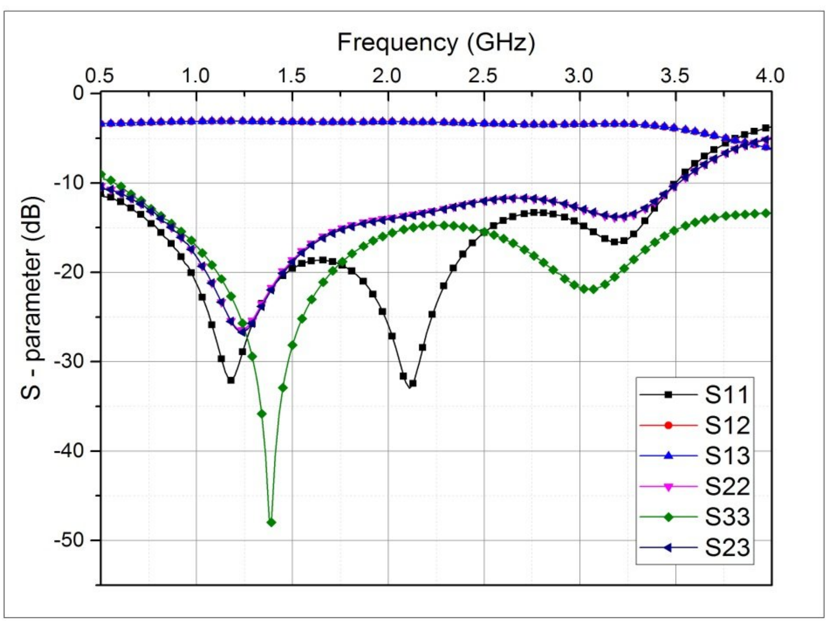

Fig.4 SimulatedS- Parameters S_{11}, S_{22}, $S_{33,}$ $S_{21,}$ S_{31} and S_{23}

From the Fig. 4 the return loss S_{11} of the power divider is below -10dB from 0.5 to 3.5 GHz. The output return loss $S_{22}$is below -10dB from 0.5 to 3.5 GHz and S_{33} is below -10dB from 0.58 to 4 GHz. The Insertion losses S_{21} and S_{31} of the power divider is -3.08 to -3.9 dB from 0.5 to 3.51 GHz and the isolation S_{23} is below -10dB from 0.5 GHz to 3.5 GHz.

MEASURED RESULTS

The fabricated power divider is measured using Agilent FieldFox N9923A vector network analyser. The fabricated proposed power divider is shown in Fig. 5. The measured results of different S-parameters S_{11}, S_{22}, S_{33}, S_{21}, S_{31} and $S_{23}$are shown in Fig. 6.

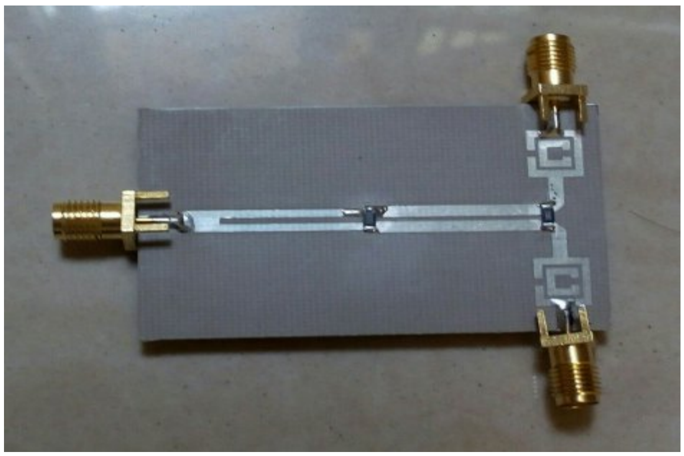

Fig. 5 Photograph of the proposed power divider

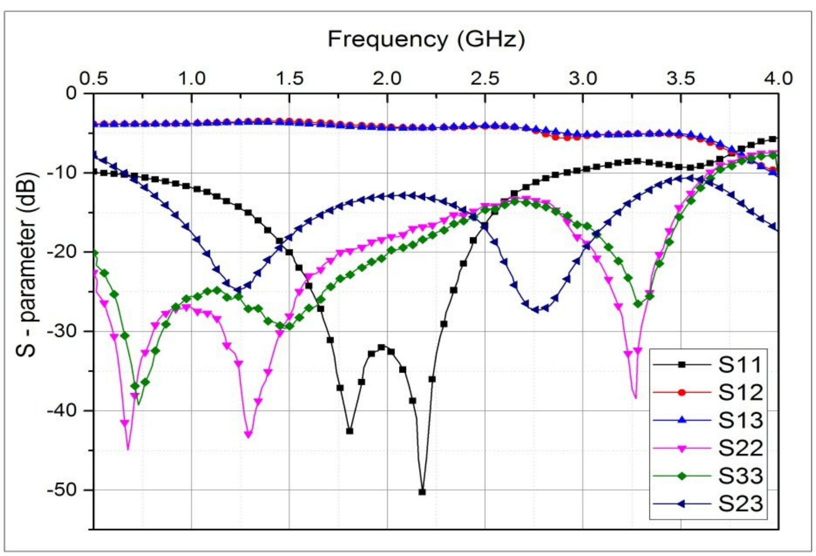

Fig. 6 Measured S- Parameters S_{11}, S_{22},S_{33}, S_{21}, S_{31} and S_{23}

The measured results show that the input return loss S_{11} is below -10 dB from 0.553 to 2.9 GHz. The output return losses S_{22} and S_{33} are below -10 dB from 0.5 to 3.65 GHz. The isolation S_{23} is below -10 dB from 0.65 to 4 GHz. The insertion losses S_{21} and S_{31} are -3.48 to -5.5 dB from 0.5 to 3.5 GHz. Therefore this power divider has good matching, isolation and insertion loss for wide band operation between 0.5 to 2.9 GHz which is suitable for 2G, 3G and 4G mobile communications.

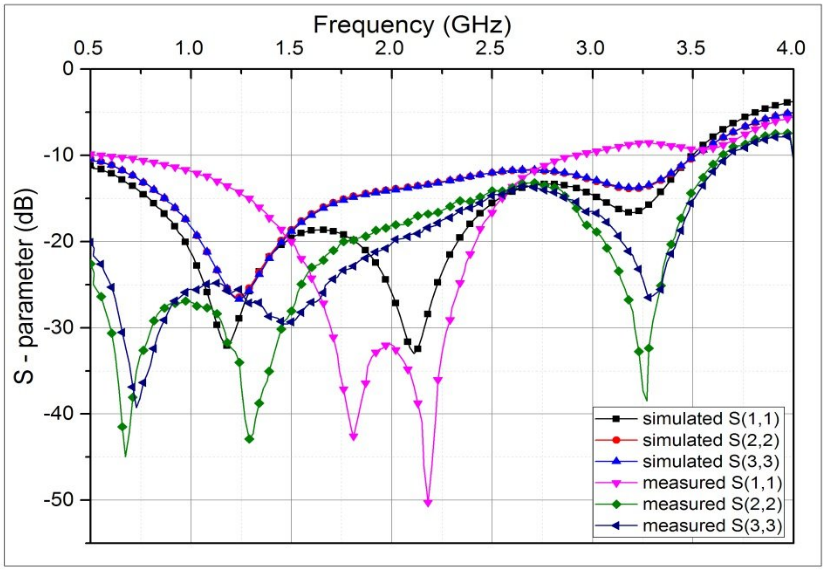

Fig.7 Comparison between simulated and measured result of S_{11}, S_{22} and S_{33}

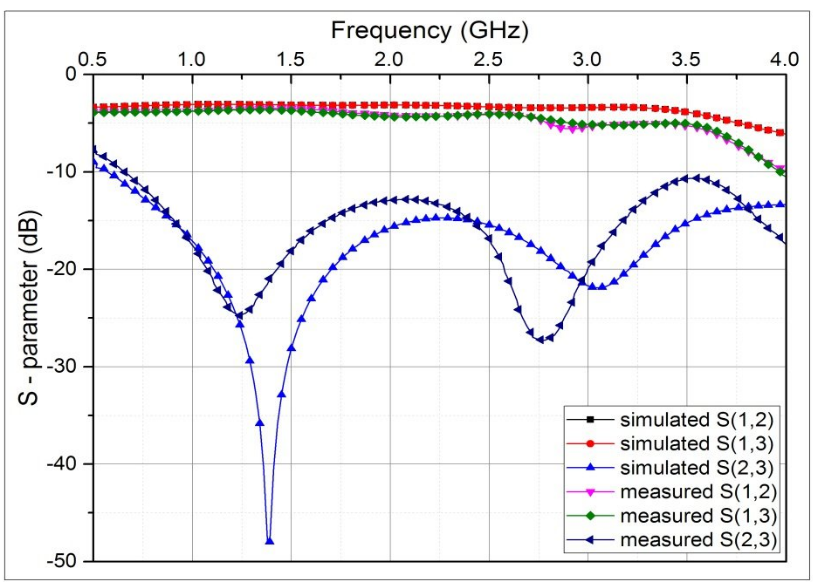

Fig.8 Comparison between simulated and measured result of S_{21}, S_{31} and S_{23}

The Fig. 7 and Fig. 8 show the comparison between simulated and measured result of S_{11}, S_{22}, S_{33}, S_{21}, S_{31} and S_{23} parameters. This shows that the simulated and measured results agree with each other.

CONCLUSION

The bandwidth of the existing coupled line dual band power divider operates at 1.1 and 2.2 GHz is improved to 0.5 to 2.9GHz is proposed.Hence, the proposed power divider works under the wide range of bandwidth.Metamaterial structureis used to enhance the bandwidth. The bandwidth of power divider is 2.4 GHz. It has the enhanced the bandwidth compared with the previous dual band coupled line power divider. The return loss is also reduced up to -50 dB. Isolation between the ports is obtained -27 dB. Insertion loss is maintained between -3.48 to -5.5 dB.So, the proposed power is well suited for L Band, S band applications and it is used for mobile phone applications up to 4G.

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